Future Trends in Distributed Simulation and Distributed Virtual Environments

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Results of a Peer Study

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HLA*forum*10

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Study Background

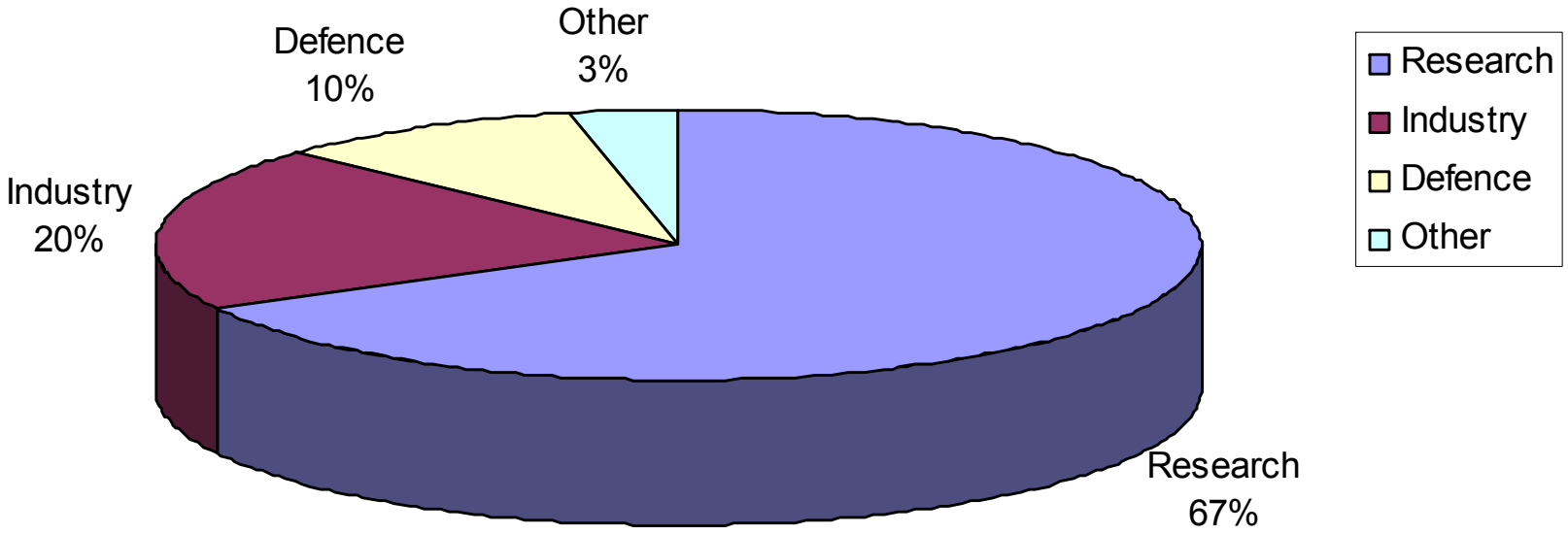
- Independent peer study
  - Initiated by Fraunhofer IFF, Magdeburg
  - Contracted to an independent team of researchers
  - Aligned with attempt to establish an "Innovation and Research Center for Distributed, Interoperable Virtual Reality and Simulation"

- Objectives
  - Assess the current state in the fields "Distributed Simulation" and "Distributed Virtual Environments"
  - Assess practical relevance
  - Identify open research challenges

- Survey on the subject matter conducted among experts in the fields as main part of the effort

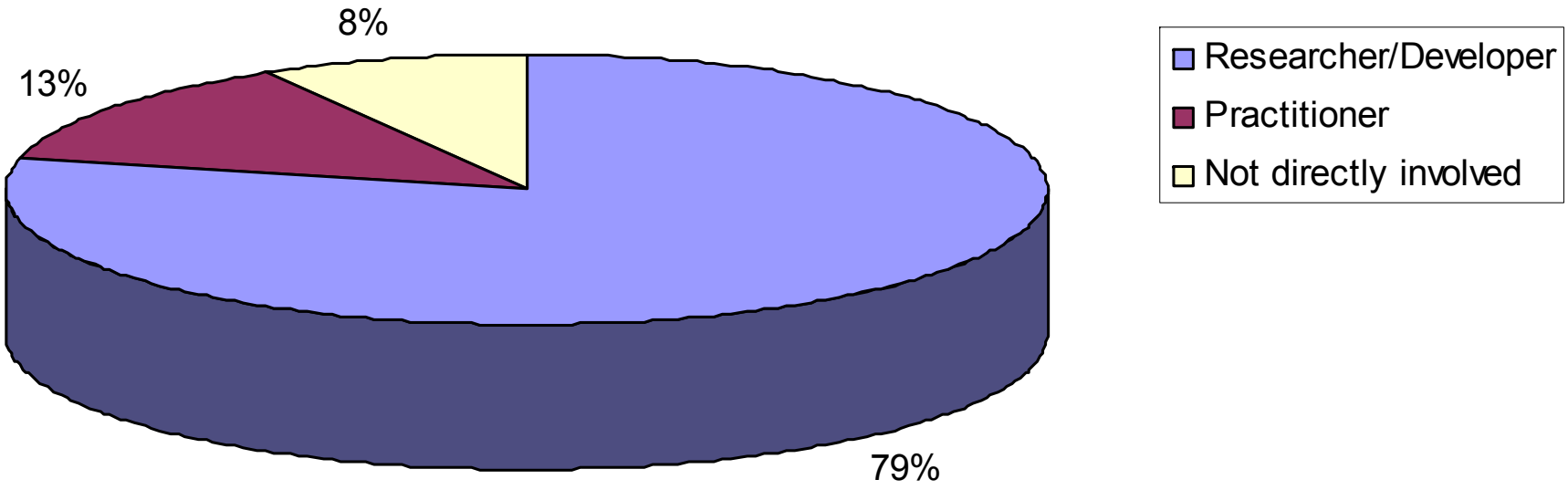
Classification of the Survey Participants

- Distribution of the survey by email through several relevant conference distribution lists (SISO, WSC, PADS, DS-RT, ASIM)
- Deadline for Returns: October 15, 2007 (Cut-off-Day: November 1, 2007)
- Total number of returned questionnaires: 61
- Classification of participants – see figure



Relationship of Participants to Distributed Simulation and Distributed Virtual Environments

- 92% of participants are directly involved with the topics, in total 79% as Researcher/Developer and 13% as Practitioners
- Answers of the participants can thus be expected to give substantiated statements towards the state-of-the-art of the research as well as towards open research requirements



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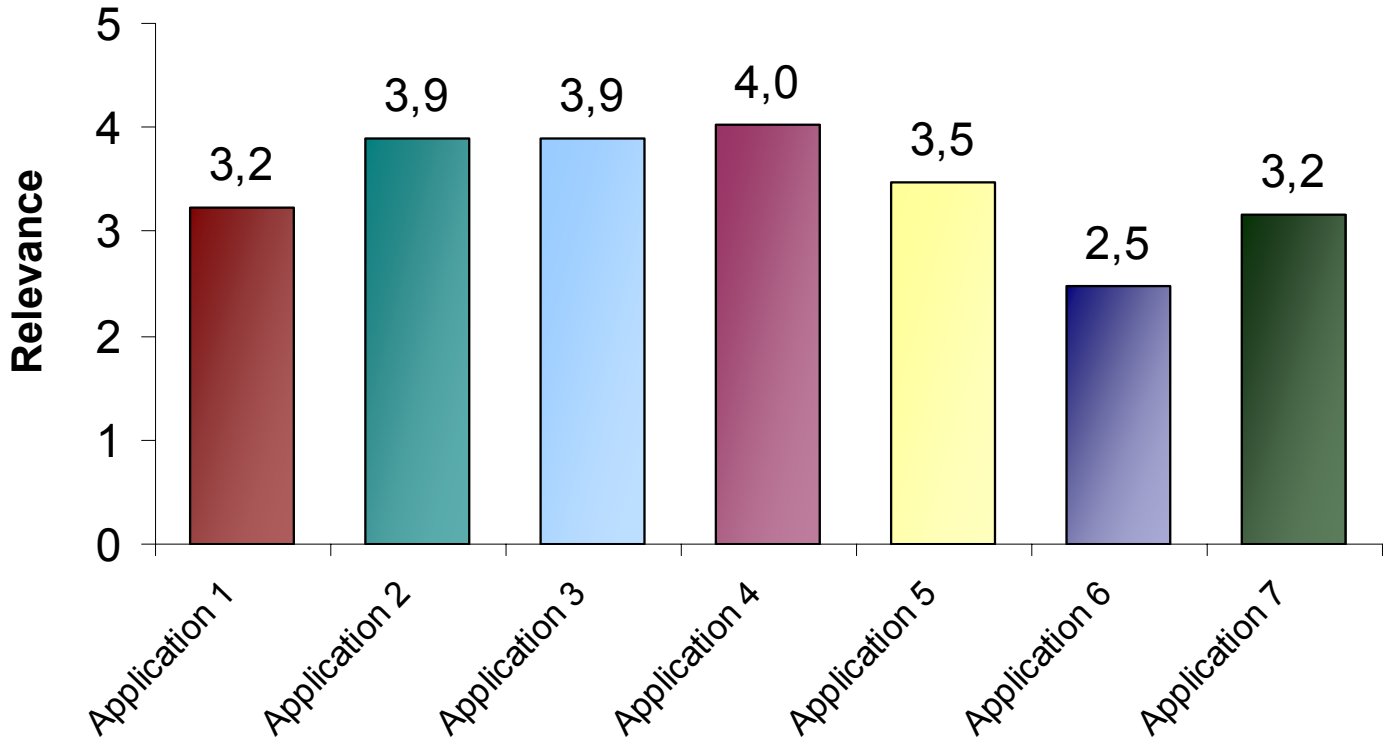
Question 1.1: Future relevance of potential applications of DS/DVE technologies for improving internal processes



Potential Applications for Process Improvements

- Application 1: DVEs for improving the communication between company sites
- Application 2: Distributed Training Sessions
- Application 3: Joining computer resources for complex distributed simulations
- Application 4: Integrating heterogeneous resources for distributed simulations
- Application 5: Distributed Design Reviews
- Application 6:DVEs as a replacement of video conferencing technologies
- Application 7: DVEs as an enhancement of video conferencing technologies

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Question 1.1: Please rate the future relevance of the following potential applications of the DS/DVE technologies for improving internal processes within companies (including their suppliers) or other organizations. Please give grades in the range from (5) = highest relevance to (0) = no relevance!

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Question 1.2: Additional relevant applications for improving internal processes

- Open question for collecting additional interesting suggestions for applications for improving processes
- Answers (clustered):
  - Integration aspects
    - Distributed simulation (DS) allows geographic separation of simulation tools (and resources) from the point where they are needed
    - Different company locations (+ suppliers) can join their simulation resources and thus improve their cooperative processes (e.g. supply chains)
    - Distributed Design – not only Distributed Design Reviews, but the entire distributed design process is an applications for both DS and DVE
    - DVEs enable better communication between various project actors (manager, architects, designer, end-user, …)
  - Product Development
    - Remote product testing (product simulator at one place, testers anywhere), also for marketing purposes
    - Knowledge protection in distributed product models: with distributed simulation, know how can be protected, but product can still be simulated as a whole

Question 1.2: Additional relevant applications for improving internal processes

- Production
  - Distributed planning of manufacturing lines (join planning of suppliers and OEMs)
  - Direct process control of automated production processes (simulation based Command&Control center)

- Miscellaneous
  - Distributed Virtual Environments as Market Places for Sub Contractors on the Internet
  - 3D web: Current 2D web will be combined with DVE capabilities (e.g., as known from applications like Second Life)
  - Real-time decision making using DS/DVE
  - Analysis and feedback loop for developing interpersonal skills for management and teamwork

Question 1.3: Relevance of distributed simulation (DS) and distributed virtual environments (DVE) for improving the life cycle of future products (e.g. product design, operation, maintenance)

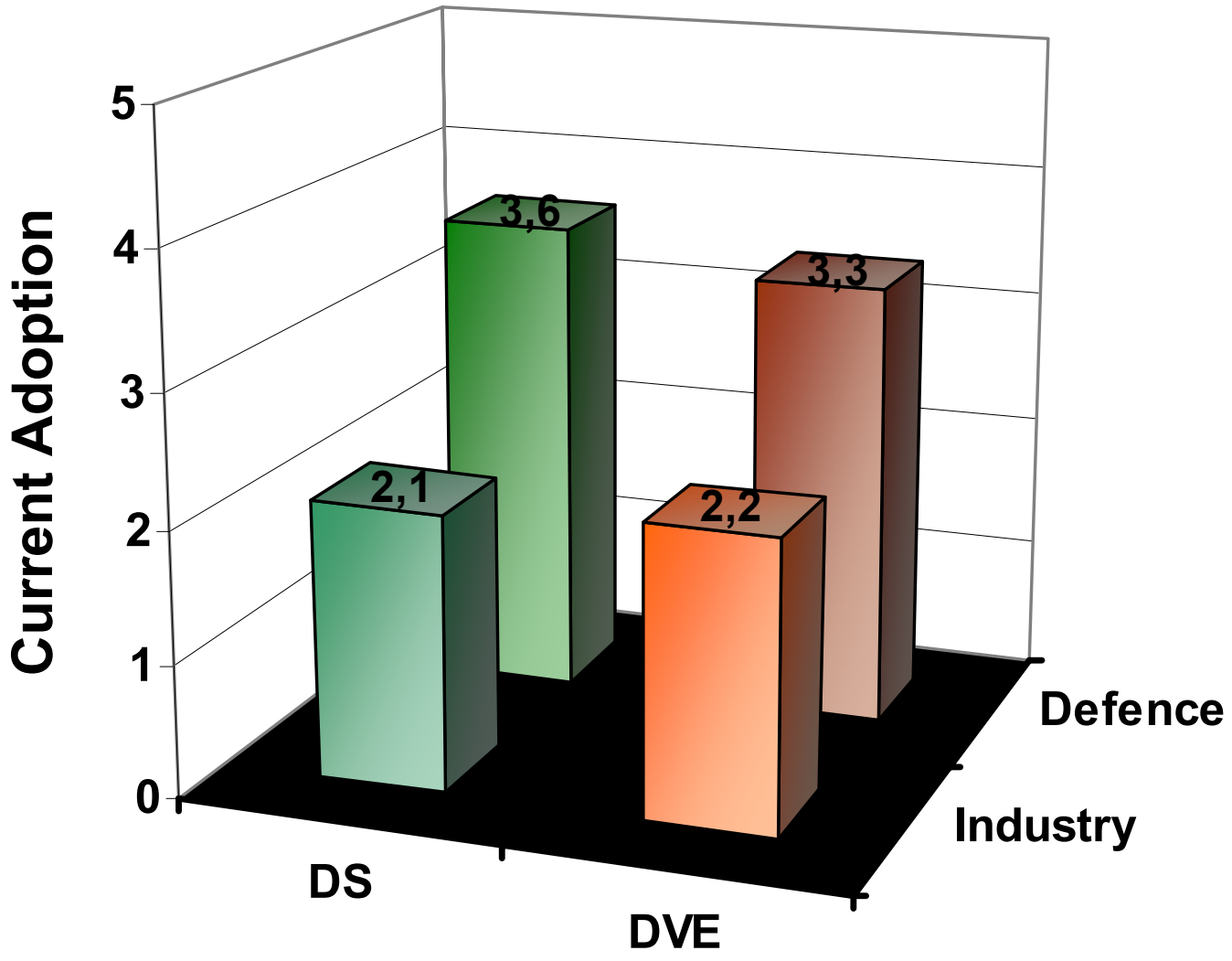
Possible Answers
5 – Very High
4 – High
3 – Medium
2 – Low
1 – Very Low
0 – None

- Mean Value of all answers

3,9 (= High)

- Answered by 98% of participants
- Rather small standard deviation (0,9)
  -> high degree of agreement

Question 1.4: Current adoption of the technologies in industry and defense



Possible Answers

5 – Very High
4 – High
3 – Medium
2 – Low
1 – Very Low
0 – None

Question 1.4: Current adoption of the technologies in industry and defense

- Interpretation of results and comments
  - Defense community:
    - As expected, the military domain already makes a rather good use (between medium and high) of distributed simulation and distributed virtual environments
    - Reasons are obvious: Military training and acquisition highly relies on both technologies and standards like HLA and DIS originate in the military
    - Still, it is questionable, why application degree in military is not “very high”, this may indicate more research necessities
  - Industry:
    - Low usage of DS/DVE in industry (combined with the results from questions 1.1 through 1.3 which confirm relevant application areas) indicates the lack of good technical solutions and the need for basic research in this area
    - Existing solutions may be focused on the needs of the military and may not sufficiently take into account industrial requirements
    - Some respondents indicate large variance of adoption in industry: esp. SMEs cannot access these technologies at all
    - Missing recognition: not only technical reasons prevent usage, but also acceptance and appreciation is missing, and prejudices (expenses, invasive and disruptive character of DVEs) must be overcome
    - Clear business cases (ROI, return on invest) needed

Question 1.5: Economic potential of the technologies distributed simulation and distributed virtual environments

Possible Answers
5 – Very High
4 – High
3 – Medium
2 – Low
1 – Very Low
0 – None

- Mean Value of all answers

3,7 (= High)

- Answered by 90% of participants
- Rather small standard deviation (1,0)
  -> high degree of agreement

Question 1.5: Economic potential of the technologies distributed simulation and distributed virtual environments

- Areas with highest economic potential
  - Defense: Mission training and rehearsal, Decision Support, Technology Acquisition
  - Emerging Markets: Global Environmental Problems, Emergency and Security Management, Homeland Security
  - Distant Learning Technologies including advanced Training Solutions
  - Gaming Industry
  - Manufacturing
  - Product Development
  - In general: any area that has to communicate complex information

- A few also argue, that economic potential is limited because of the expenses related to using these technologies (they are still too costly)

Question 1.6: Future Developments in the cooperation between OEMs and suppliers which could make DS/DVE usage inevitable

- Business environment
  - Lack of money and increasing competition leads to forming of clusters (aka globalization) - this requires increased cooperation among OEMs and builds demand for DS/DVE technologies
  - Increasing need for protection of IPR (intellectual property rights) – this will increase the need for secure component-based distributed simulation
  - Increasing importance for try-before-buy approach (choice of right sub-components for integration in the final product)

- Technological advances
  - High bandwidth and fast network/communication technologies
  - Lower cost equipment
  - Interim technologies between traditional 2D (paper) documents and 3D environments (can help to get accustomed the new 3D technologies)
  - Adoption/emulation of game technologies for simplified use and reduction of barriers

Question 1.6: Future Developments in the cooperation between OEMs and suppliers which could make DS/DVE usage inevitable

- Ready and robust solutions
  - Reliable standards are indispensible
  - Availability of trustworthy tools
  - Standardized ontologies for out-of-the-box (semantic) interoperability – not only syntactic connectivity

- Success stories
  - Needed to overcome psychological barriers
  - Customer demand must trigger technological advances
  - Pilot applications which demonstrate benefits

Question 1.7.1: Opinions towards the industrial relevance of the distributed virtual online community “Second Life”

- Industrial relevance mainly in areas like advertizing and marketing, some potential for improving communications (some within the company, but especially in communication with customers)

- More serious industrial applications are questioned many respondents
  - Problems: fidelity and resolution not appropriate for “serious” applications
  - Less effective than video conference
  - Privacy issue: Too little user verification and separation from personal activities (One participant answered that “you cannot keep naked avatars out of your business meeting”)
  - But: Other DVE products are emerging which may better address the needs for business uses

Question 1.7.2: Weaknesses (technical, conceptual, …) of “Second Life”

- Technical
  - Lack of fidelity and resolution
  - Missing security, missing user verification and control
  - Limited graphics; inability to build content with standard 3D tools and import the content
  - Limited protocols for articulations and component motion
  - No open standards, closed interfaces
  - Scalability, bandwidth requirements, missing compressing technologies

- Conceptual:
  - Unfocused character: no appropriate tools for (say) engineering tasks
  - relation of virtual money and real money is depending on one company, difficult bases for making real business

Question 1.8: Non-Military “Killer Applications”

- Decision support systems for homeland security / catastrophes / crisis situations
  - Simulation of effects and counter measures (rescue operation)
  - Simulation of complex critical infrastructures
  - Virtual training for rescue teams
- Space exploration
  - DS/DVE as Command and Control tool for remote operations
  - Sending humans virtually where they cannot go physically
- Virtual Meetings
  - For technological development and design teams
  - For project progress meetings
  - For Social Interaction and Entertainment
- Virtual Training Applications in general
  - Combination of one or multiple users with real and simulation equipment
  - Training in truly geographically and internationally distributed contexts (e.g. for the International Space Station, ISS)

Question 1.8: Non-Military “Killer Applications”

- Virtual Travel on street level
  - Google Earth as a starting place – people which can travel virtually and meet in realistic synthetic environment
- Emulation
  - Couple real equipment with simulated parts of reality
  - Multiple real controllers connected to a DVE
- Industrial supply chain simulation
- Real Estates and Home Design
  - Visualize and enter future houses in actual environment in which it will be build
- Cultural education
  - Create history and arts museums as a DVE, display artifacts in the real context in which they existed
- Sales Activities
  - Driving a new car on any road of the world

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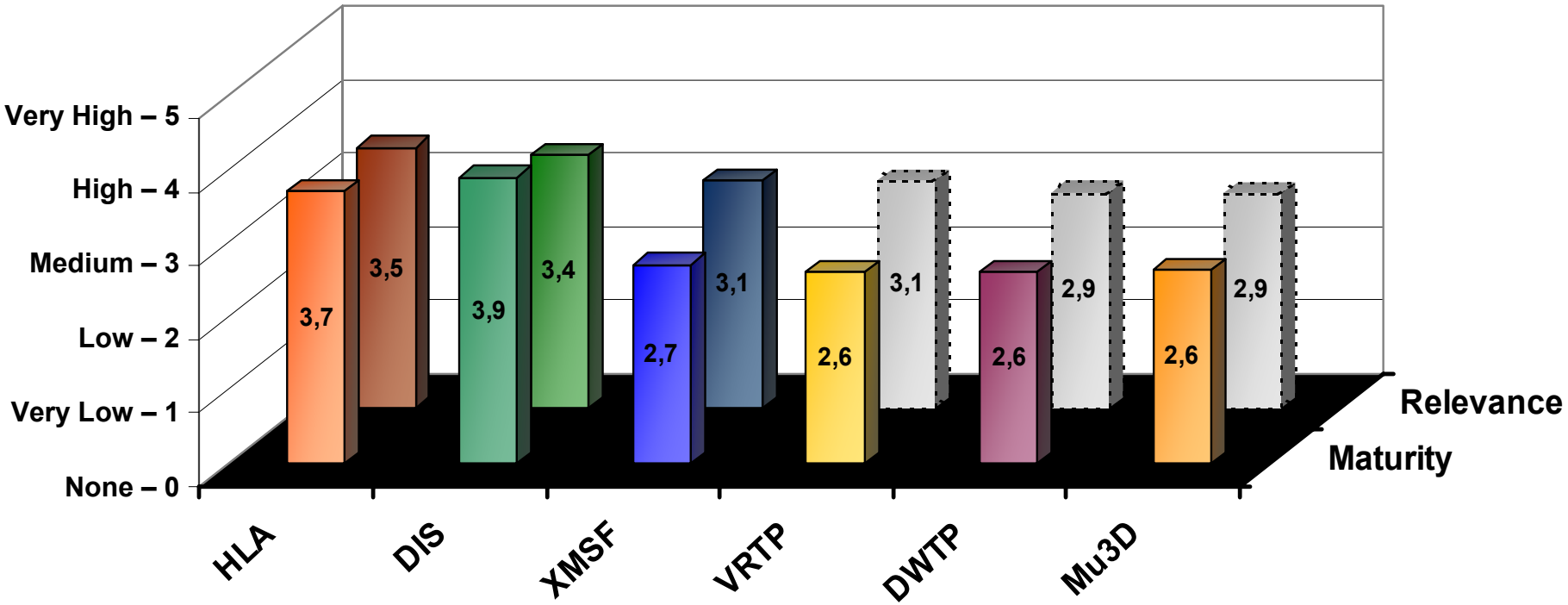
Question 2.1: Current Research Activities of other groups active in the DS/DVE field

- Application areas for DS/DVE technologies
  - homeland security
  - emergency management
  - manufacturing & logistics
  - military simulation (training, weapons)
  - complex technical or natural systems (particle, material, climate)
- Research towards base technologies
  - effects of wide area network latency of real-time and interactive distributed simulations
  - combining discrete event simulations with distributed simulation
  - fundamental interoperability mechanisms
  - Synchronization algorithms
  - Distributed haptic DVEs
- Interdisciplinary activities
  - Integration of game technology with advanced simulation technologies to leverage the strengths of both
  - Simulation based Command and Control (C2) systems
  - Agent-based approaches for decision making in DS/DVE

Question 2.3: How would you rate the maturity and practical relevance of the following standards and protocols?



- Only HLA and DIS are known to the majority of participants (~80%)
- XMSF is known by app. 50% of the participants
- Statements towards practical relevance of VRTP, DWTP and Mu3D are questionable, since these protocols are only known by a minority of the participants (VRTP: 34%, DWTP: 21%, Mu3D: 18%)

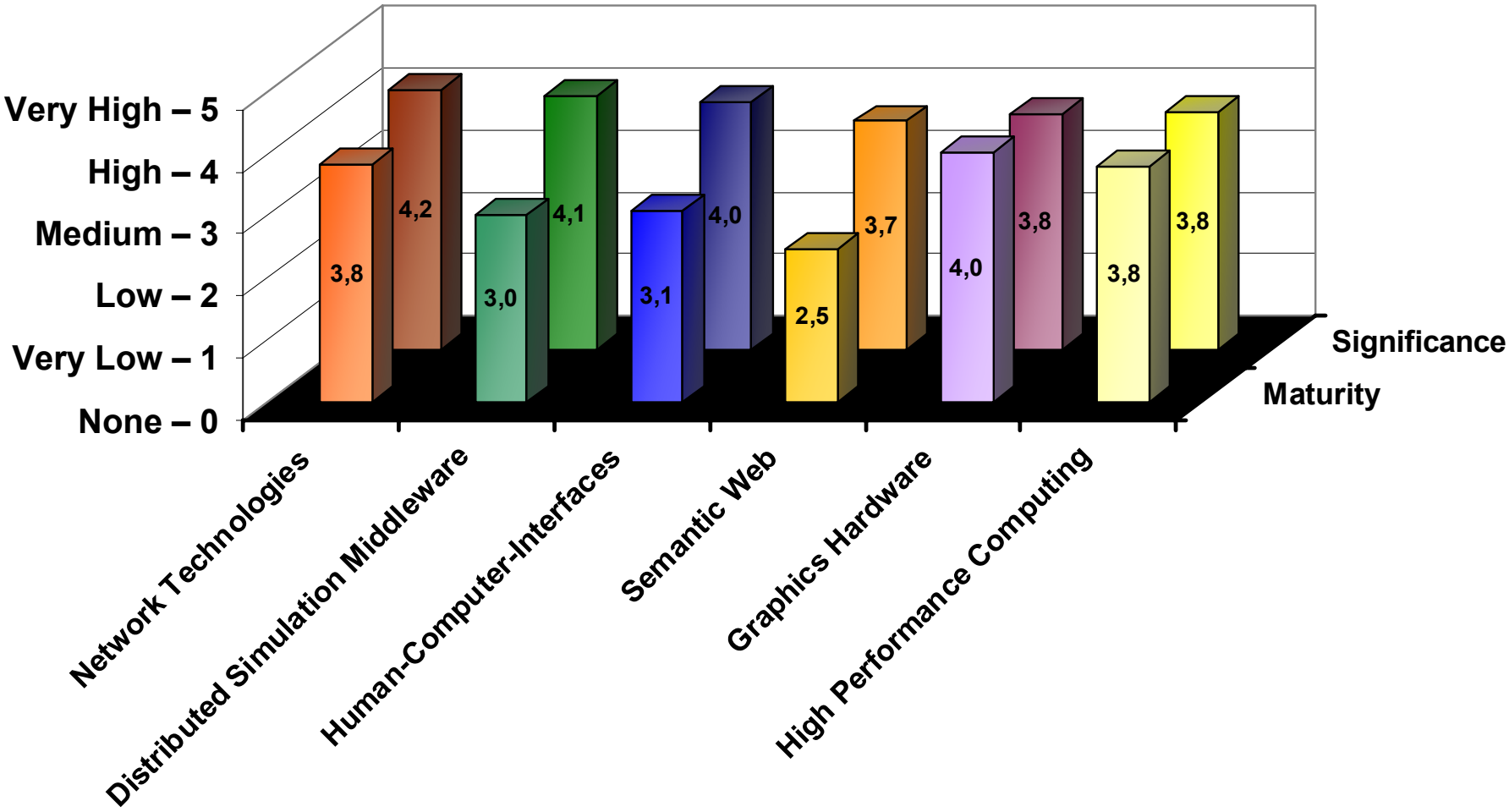
Question 2.3: How would you rate the maturity and practical relevance of the following standards and protocols?

- Although HLA and DIS seem to be well established in the market, several weaknesses concerning theses approaches have been commented:

- Weaknesses of HLA:
  - No load-balancing as part of the standard
  - Bad Scalability
  - Too much reliance on Peer-to-Peer structures, large DVEs may be better of with client-server structures where multiple servers are peers of each other
  - Covers only syntactic interoperability (not semantic)
  - Standard is too „heavy“, i.e. very complex, difficult to learn and thus to adopt and use

- Weaknesses of DIS
  - PDU concept allows no interest management (publish/subscribe) and no load balancing
  - Limited conceptual versatility (i.e. only applicable to real-time simulations)
  - Restriction to a single domain
  - Limitations of the standard lead to proprietary modifications and custom implementations that do not allow re-use outside original application

Question 2.4: Maturity of base technologies needed to implement DS/DVE applications and their significance for advancing the fields



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Question 2.4: How would you rate the maturity of the following underlying base technologies needed to implement DS/DVE applications and their significance for advancing the fields of DS/DVE?

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Question 2.4: Maturity of base technologies needed to implement DS/DVE applications and their significance for advancing the fields

- How to interpret the diagram:
  - To determine the interesting research areas for INCENTIVE (or DS/DVE research in general), one should look for the areas which currently have the lowest degree of maturity, but still have a high rating towards its significance for advancing the fields of DS/DVE
  - In our specific case, this would indicate
    - Distributed simulation middleware
    - Human-Computer-Interfaces, and
    - Semantic Web (as a placeholder for approaches supporting semantic interoperability)

    as the fields rated most significant to work on

- Comments towards required improvements for each base technology
  - Network technologies
    - Lower latency and better bandwidth
    - Robustness and fault tolerance
    - Security
    - Quality of Service (QoS) specifications
  - Distributed Simulation Middleware
    - Plug-and-Play capabilities
    - Standardization (also: Interoperability between different *standards*)
    - Must allow for semantic connectivity
    - Needs to be ubiquitous, i.e. accessible anywhere with any device

Question 2.4: Maturity of base technologies needed to implement DS/DVE applications and their significance for advancing the fields

- Comments towards required improvements for each base technology (continued)
  - Human-Computer-Interfaces
    - Multimodal interfaces, also haptics, without data cloves
    - Environments must become more immersive
    - Change focus needed to enhanced reality instead of virtual
    - Usability must greatly be improved
    - Trend must go towards human-centered interfaces
  - Semantic Web
    - Defining semantics through ontologies is not yet mature
    - Ontologies cannot be the only answer
    - Standardization of terms of reference for certain domains could help
    - Ways to transform the current know-how stored in the WWW into a semantic web knowledge
  - Graphics Hardware
    - Better physics integration
    - Promotion of standardization
    - Already very good developed, breakthroughs not to be expected, unless some completely new paradigm comes up (e.g. "no triangles needed any more")
  - High Performance Computing
    - involvement of all heterogeneous nodes into the universal grid
    - Demonstration of application potential to broader community
    - Tools to use high performance computing in engineering software environments

Question 2.5: Overall Maturity of the Technologies and Solutions developed within fields of the DS/DVE

Possible Answers

4 – Very mature and already applied for many practical applications
3 – Mature, but not applied widely yet
2 – In the process of maturing
1 – Technologies exist, but still have significant weaknesses
0 – Academic research/prototypes

- Mean value of all answers:

2,1 (in the process of maturing)

- Interpretation:

DS/DVE technologies have been around for some time now, however, there are still weaknesses and technological issues which need to be resolved and more basic research is needed to bring them to a wide-spread and cost-efficient usage

Question 2.6: Research Challenges in the areas of DS/DVE which qualify as “Grand Challenges”

- Solving the intrinsic conflict between desire for high interactivity / response times and the need for maintaining consistency in DVEs
- Easy to use synchronization algorithms which solve the "zero lookahead problem“
- True plug-and-play simulation capabilities
  - Standard approach to couple the distributed models and its acceptance by industry
  - Interoperability for Multi-level resolution models
- Automatic or semi-automatic interoperability between domains (ontologies, standard reference models, metamodels)
- DVEs of the future
  - realistic real-time visualization with full account of underlying physics and integration of voice and sounds
  - Living Dynamic World, i.e. the creation of a world that is constantly active and evolving, even if there are no human players plugged in
  - Use of city sized large scale mobile nodes in reasonable speed

Question 2.7: Findings and Results expected from an external research group

- Integrate research, development, utilization, and education of DS/DVE
- Setting an agenda of research and development both short and long term
  - identifying important trends
  - creating a forum for prime actors to interact and collaborate
  - Definition of reference models
  - Definition of standard approachs
- Solutions to the Grand Challenges
- Expand the predominant application fields of DS/DVE to industry, design, manufacturing, and consumer sector
  - demonstrate how research translates into real use
  - integrate findings with a variety of needs in industry, manufacturing, health care, security, environment, and education

Question 2.9: Interesting Trends, Solutions, Actors which could be considered drivers in the field of DS/DVE

- Trends:
  - Increasing popularity of Personal Computing Devices
  - Service oriented architectures
  - Ambient networks
  - Open Source Solutions
  - Rising importance of homeland security and critical infrastructure protection
  - Ubiquity of visual media
  - expectation of instant easy communication (cell phone, I-pod, email, …)
  - augmented reality systems
  - the introduction of haptic and other multimodal interfaces

- Actors:
  - Gaming Industry
  - Defense Agencies (US DOD, German Armed Forces' IT-Agency)
  - SISO (Study Groups, Product Development Groups)
  - Marketing Decision Makers

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Summary and Conclusions

- Both DS and DVE are characterized as having a high practical relevance and a high economical potential

- However, current adoption of DS/DVE in industry is limited
  - Clear business cases must be articulated
  - Only limited number of success stories
  - Technical immaturities (no plug-and-play standards, no semantic interoperability, …)

- Grand Challenges
  - Solutions to intrinsic conflict in DVEs (high interactivity vs. consistency)
  - Solutions to the “zero lookahead” problem
  - true plug-and-play simulation capabilities
  - (semi-) automatic semantic interoperability between domains.

- Influencing Trends
  - increasing popularity of personal computing devices
  - existence of ambient networks
  - expectation of instant and easy communications